Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

SHORTER ARTICLES AND DISCUSSION

"HOMING" BEHAVIOR IN CHITON[1]

1. A STATEMENT concluding a recent preliminary account of the "homing" habits of the pulmonate *Onchidium floridanum* (Arey and Crozier, 1918) reads as follows:

> To the extent that the homing habits of *Onchidium* may be proved to involve associative memory, this snail may be placed in a series comprising such types as *Chiton, Fissurella, Onchidium* and *Octopus,* all four of which, in a sense, exhibit homing behavior, but of increasing degrees of precision and complexity in the order of arrangement here given.

The observations warranting a contention of this sort, so far as it involves *Chiton,* were not fully available when our analysis of the sensory responses of *Chiton tuberculatus* (Arey and Crozier, 1919) was written, and I have therefore considered it appropriate, as an addition to that report, to indicate the nature of the facts leading us to ascribe to *Chiton* a certain degree of "homing" behavior.

2. It was noted by Heath (1899, p. 4), on the Californian coast, that the adult *Ischnochiton magdalenensis* is found during the day under boulders between tides, but that at night the mollusc comes out to feed on seaweeds growing upon the rocks, retiring to dark situations after sunrise. Species of *Mopalia,* and *Cryptochiton,* were found to "remain out on their feeding grounds only when the day is foggy or dark." Numerous other species are more or less photonegative (cf. also Crozier, 1919*b*), but some nevertheless continuously occupy situations brilliantly illuminated (cf. Heath, 1899, p. 4; Plate, 1901; Pelseneer, 1906, p. 50). It has been shown elsewhere (Crozier and Arey, 1918; Arey and Crozier, 1919) that young individuals of *Chiton tuberculatus* are photonegative to ordinary daylight, the older ones photopositive. This matter of photic irritability is intimately concerned with certain diurnal movements simulating "homing" behavior.

Heath (1904) was of the opinion that the bilateral larval eyes of some chitons, persisting as they do well into postlarval life, until the shell plates become opaque, might be functionally important in determining responses to light. Earlier, he had noted (1899, p. 4) that the ventral soft parts of *Ischnochiton,* especially the proboscis, might be sensitive to light, and it has been stated in a general way (Pelseneer, 1906, p. 50) that chitons in which there are no obvious shell "eyes" seem, nevertheless, to be sensitive to illumination. Direct proof has, however, been given by Arey and myself (1919) that the tegmental æsthetes of *Chiton tuberculatus* are photosensitive, and that this form of irritability is important in determining the habitat of an individual chiton.

---

[1] Contributions from the Bermuda Biological Station for Research. No. 127.

C. tuberculatus attains a mean age of about 8 years (Crozier, 1918*a,* 1918*b*). As it grows, the periostracum and the surface of the tegmentum become eroded, and the superficial photoreceptive organs destroyed (Arey and Crozier, 1919). There is an almost perfect correlation between the degree of this erosion and the relative illumination of the situations frequented by these chitons. The analysis of this state of affairs, and its implications, will be more fully considered in another place, but as an illustration I cite the following record, which is quite typical of many others:

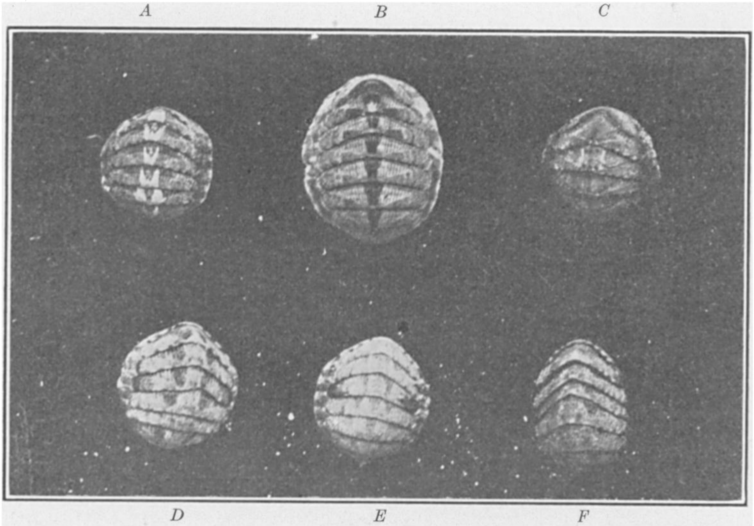

FIG. 1. Illustrating the relative lengths, ages and degrees of shell-erosion in three groups of *Chiton tuberculatus* taken from localities quite near together, but in the different situations indicated. The extent of erosion seen in each specimen was estimated by comparison with a graded series of "standard" chitons: *A,* signifying *no erosion; B, slight erosion; C, a more severe stage, but mild in comparison with D and E,* the last representing *relatively extreme destruction of the tegmental surfaces.*

July 1, 1918. At the northwest end of Marshall, Idaho, a small cove bounded on the west side by rocks exposed to the sunlight of a cloudless day; the cove covered by loose slabs of rock, piled upon one another; both situations, the exposed rock surface and the under sides of the loose stones, yielded a number of chitons.

From the sunny rock surface, 38 individuals were obtained, ranging in length from 5.5 to 8.9 cms., and in estimated age (Crozier, 1918*a*) from 5 to 11 years. These were without exception seen to have the tegmenta eroded to a greater or less extent.

From several crevices in the rock, having their deeper recesses well sheltered from the sun, 8 specimens were secured. These were 4.5–6.9 cms. long, 4–6 years old, and but slightly eroded.

Under the stones, 30 chitons were collected. There were 3.4–6.9 cms. long, 2–7 years old, and at the most very mildly eroded.

Fig. 1 exhibits, for these lots, the distribution of: (1) length, (2) age, and (3) degree of erosion. The "degree of erosion" of the shell plates was judged empirically by comparison with a graded series of "standard" examples, a method sufficiently precise for the purposes of this illustration.

It is obvious from the figure that those chitons with relatively uneroded shells are younger, smaller, and live in darkened situations; whereas the older individuals, larger, with much eroded shells, occur in the bright sunlight; those taken in partially illuminated cracks and crevices are of intermediate size and age, and their shells exhibit an intermediate degree of erosion,[2] these characteristics affording, in fact, an ethological definition of a certain portion of the chiton population. The individuals of this general "intermediate" class are frequently so situated that they exhibit the type of "nocturnal" activity noted by Heath (1899) for several species—they creep over open rock surfaces, feeding, at night, and may remain out there on dark and gloomy days, but return to crevices (or to the partial shelter of large stones) when the rising sun is of ordinary brilliancy.

The uneroded chitons are photonegative to moonlight, even, and although moving about actively at night, do not provide data bearing on the possibility of "homing." This is largely true because the photonegative response of the younger, uneroded, chitons becomes altered, depending upon the destruction of the tegmental receptors, in the directions of a photopositive reaction to ordinary daylight; this alteration depends, not on age, but upon the degree of intactiveness of the photoreceptive apparatus, and its importance in the present connection is due to the fact that the chitons of intermediate age, eroded to a moderate degree, and less photonegative[3] than the smaller ones, come to occur in places where moderate illumination prevails. Moreover, they move about much more freely than the younger individuals, thus often getting some distance away from loose rocks, not plentiful along many stretches of shore line. Crevices of one sort or another, or shaded depressions, are therefore the one type of refuge open to them.

---

[2] There are several methods of estimating rather precisely the exact amount of erosion in any given case. In a later paper these methods are fully made use of in analyzing the observed distributional occurrence of the Chitons.

3. It was found, by observing a group of marked chitons each day for a month, that the older ones and those of the "intermediate" group do not wander readily from place to place (Arey and Crozier, 1919). Another group containing 14 chitons of the "intermediate" class as above defined was under daily observation for three months, and the behavior of this group strongly suggested a feeble kind of "homing" phenomenon. The animals concerned spent most of the day under a boulder at half-tide. At night they crept out for distances of not more than a meter, feeding on *Enteromorpha* and other algæ. With the rising sun, they retreated to the rock-shelter. If the tide were out at sunrise, they remained more or less fixed until again covered by the sea, then moving toward the rock.

This sort of behavior, regularly and constantly exhibited, seemed to represent perhaps the incipient stages of a kind of "homing instinct."[4] The movements of the individuals of this group were therefore carefully watched. The bit of shore concerned faced in general southeastward, and the tiny platform over which the chitons crept while feeding was so oriented with reference to the rising sun that the photonegative orientation of the animals and their subsequent creeping brought them for the most part automatically back to the shaded hollow under the rock. But I noticed repeatedly that in some instances the molluscs moved at an angle of 30°–40° across the direction of the sun's rays, moving more or less directly toward the rock. If such individuals were suddenly detached (with the aid of a cold-chisel and hammer, removing the animal still fixed to a bit of stone), and so placed as to necessitate its approaching the rock at a different angle, it usually did so without trouble. If removed to a greater distance than 1.5 meters, no return was effected, the creature taking up a more or less permanent site in another shaded hollow.

---

[3] As worked out in a previous report (Arey and Crozier, 1919), the partial destruction of the photoreceptive apparatus through erosion is a principal factor conditioning lower stimulating power of light of a given intensity; in general, *Chiton* is actively photopositive to weak light, negative to intense light; with advancing age, therefore, the threshold for photonegativity becomes higher.

[4] Data regarding the movements of a single *Chiton* favorably situated on the side of a wharf and watched continuously for 9 months are given elsewhere (Arey and Crozier, 1919). This animal was quite old, and very much eroded. It remained in the open except during severe storms and one hurricane, when waves beat fiercely on the wharf. Under these circumstances the mollusc withdrew to a cavity at one end of the wharf, near the shore-line, and remained hidden. Several other cavities were available, but this particular one was automatically encountered as the *Chiton* moved shoreward on the wharf-side and away from the more exposed outer edge of the wharf. One wonders what the anectodotalist would make of a case like this!

Aside from light, it must be remembered that there are other possible directive agencies in such a case. The sea was rarely still, and even a slight tidal current would be sufficient to reflect pressure waves from the shore,—so that, perhaps by this means in part, a chiton would be oriented toward shore, and thus, in the present case, inevitably toward its rock-pocket. Additional specimens of the general "intermediate" group, brought from distant islands, were "planted" in this community, and engaged in the same nocturnal wanderings and early morning returns.

4. Without further analysis, the activities of a group of Chitons such as that described, may seem to involve a sort of behavior resembling the well-known "homing" of *Fissurella*[5] and its allies. Yet with *Chiton* the matter is clearly less definite than in other instances recognized among molluscs, and, so far as I have seen, the facts may readily be interpreted in terms of immediate directive stimulation. There is nothing necessarily *specific* about the Chiton's "home." For this very reason such homing movements as *Chiton* may exhibit at a certain period of

[5] I encountered a curious instance of the "local habitation" affected by limpets, when examining the chitons of a reef on the south shore of Bermuda. One of these chitons bore on its back a small *Fissurella*, the margin of the shell of which had become so modified that it fitted nicely one particular spot on the much curved surface of the third valve of the chiton. Under water, the *Fissurella* wandered over the eroded shell of the large chiton, feeding upon epiphytic growths, but always returned to its "home." The *Chiton* was 9.3 cms., the *Fissurella* 0.9 cm. long.

its life-history may be taken to represent one extreme in the development of such behavior among molluscs, seen perhaps in its highest condition in *Octopus* (cf., *e.g.*, Cowdry, 1911).

W. J. Crozier

PAPERS CITED

Arey, L. B., and Crozier, W. J.
1918. The 'homing habits' of the pulmonate mollusk Onchidium. *Proc. Nat. Acad. Sci.*, Vol. 4, pp. 319–321.
1919. The Sensory Responses of *Chiton*. *Jour. Exp. Zool.*, Vol. 29, pp. 157–260.
Cowdry, E. V.
1911. The Color Changes of *Octopus vulgaris* Lmk. Univ. Toronto Studies, Biol. Ser., No. 10, 53 pp. (Contrib. Bermuda Biol. Sta., Vol. 2, No. 22.)
Crozier, W. J.
1918*a*. Growth and Duration of Life in *Chiton tuberculatus* Linn. *Proc. Nat. Acad. Sci.*, Vol. 4, pp. 322–325.
1918*b*. Growth of *Chiton* in Different Environments. Ibid., pp. 325–328.
1919*a*. On the Use of the Foot in Some Molluscs. *Jour. Exp. Zool.*, Vol. 27, pp. 359–366.
1919*b*. Note on the Photic Sensitivity of the Chitons. Amer. Nat., Vol. 54, pp. 376–380.
Crozier, W. J., and Arey, L. B.
1918. On the Significance of the Reaction to Shading in Chiton. *Amer. Jour. Physiol.*, Vol. 46, pp. 487–492.
Heath, H.
1899. The Development of *Ischnochiton*. *Zool. Jahrb.*, Abt. Anat., Bd. 12, pp. 1–90.
1904. The Larval Eye of Chitons. *Proc. Acad. Nat. Sci.*, Philadelphia, Vol. 56, pp. 257–259.
Pelseneer, P.
1906. Mollusca, in: Lankester, Treatise on Zoölogy, Pt. V, 355 pp., London.
Plate, L.
1901. Die Anatomie und Phylogenie der Chitonen (Theil C.) *Zool. Jahrb.*, Suppl. Bd. 5 (Fauna Chilensis, Bd. 2), pp. 508–600.

AN F_1 SPECIES CROSS BETWEEN HORDEUM VULGARE AND HORDEUM MURANIUM

Within the last few years the subject of species hybridization has increasingly occupied the attention of those interested in the subject of heredity. The possibility of the genetic analysis of species hybrids depends upon the ability to cross and to secure offspring from the species in question. During the course of a plant-breeding investigation which was commenced at the